Relation between Dehydration and Short Term Memory Function Impairment in College Students

[1]Annisa Bunga Nafara, [2]Mochamad Bahrudin, dr, Sp.S, [3]Annisa' Hasanah, dr, M.Si
[1]Medical Student, Medical Faculty of Muhammadiyah Malang University, Indonesia
[2]Lecturer Staff, Department of Neurology, Medical Faculty of Muhammadiyah Malang University, Indonesia
[3]Lecturer Staff, Department of Physiology, Medical Faculty of Muhammadiyah Malang University, Indonesia
E-mail: [1]annisabunga100@gmail.com, [2]mochbahrudin1012@gmail.com, [3]nisa_dr_umm@yahoo.com

ABSTRACT

According to a study in Malang city in 2013, short term memory impairment not only occur in elderly, but also in adolescence. Another study shows that 60,9% of college student in Gadjah Mada University indicated an involuntary dehydration. Losing minimum 1% of body fluid would affects brain function and cognition include short term memory function. True Experimental, Pretest and posttest with Control Group Design, 62 selected volunteers are devided into control /non-dehydration group and intervention/dehydration group (mild dehydration induced by 40 minutes treadmill in the speed of 5,6 km/h, and rest for 20 minutes). Body fluid loss at least 1%, measured by weight loss percentage. Wechsler Adult Intelligence Scale (WAIS) Digit span was used for the test instrument. Data was analyzed with Chi-Square test. Degraded posttest result indicated short term memory function impairment. 9,7% of sample with worse WAIS score in non-dehydration group and 48,8% of sample with worse WAIS score in dehydration group. Chi-Square test showed significance value of 0.001. Studies showed short term memory function impairment in intervention group was caused by the loss of at least 1% of body fluid after the exercise. Fluid Loss decreased cerebral blood flow (both volume and velocity), decreased the amount of cerebrospinal fluid, electrolyte and ion imbalance in the brain circulation and increased plasma osmolality which causes neuron shrinkage and lower brain volume (both cortex, substantia alba and ventricular system). In conclusion Dehydration is related to short term memory function impairment in college students.

Keywords: Dehydration; Memory; Students

I. INTRODUCTION

[1] Dehydration is the loss of body fluid from all compartments caused by the water intake is less that the need of fluid/loss of fluid from body. [2] Loss 1-3% of body fluid is indicated as mild dehydration. (Indonesian Health Minister, 2011). 44,5% adolescent are in the state of dehydration, [3] and only 40% male and 60% female who have adequate intake of fluid in daily basis. [4] College student is susceptible community to experience dehydration. 60,9% of college student in Gadjah Mada University were suffered from involuntary dehydration. In another side, college students are expected to get a good achievement on academic knowledge that need the process of cognitive function such as STM.

[5] Short term memory (STM) is the ability to memorize information for seconds or minutes in the certain time. [6] STM function is important to be evaluated because STM is the first process before an information is transferred to a long term memory storage (consolidation). [7] STM function impairment commonly occur in elderly (due to degenerative diseases), but recent study held in Malang showed that decrease of STM function also happen on adolescent and adult in high significant number.

[8] STM function is affected by many factors such as age, central nervous system diseases, history of head trauma, congenital abnormality, psychology, behavior and nutrition. A research showed that giving nutrition therapy with 100 grams of dates for 6 days increase in STM function of elementary students, tested with Wechsler Intelligence Scale of Children.

[9] Sleep deprivation could decrease spatial learning and memory function in sleep deprived rat, and caffeine therapy intervention (4 weeks with low dose) improved these function, tested with Morris Water Maze.

[10] Dehydration have been proven to affect blood and serum in brain circulation which are lower hematocrit count, higher osmolality of plasma, lower H2O, K^+ and glucose level. These mechanism lead to the shrinkage of neurons that cause changes of brain volume in cortex, substantia alba, and hypothalamus. [11] Due to the low level of fluid in brain, it decrease the cerebral blood flow and velocity in carotid system that supply blood to the brain. [12] Beside the changes in blood supply, lower body fluid level also affect cerebrospinal fluid production follows the degrading of ventricle volume.

[13] Studies have been conducted to determine if mild dehydration would affect brain function performance. [14] The recent investigation used exercise and heat induced acute dehydration in 25 healthy woman with average age 23 years old showed higher plasma osmolality, degraded mood, lower concentration, headache symptom. [15] A year before, in 2011 the same procedure research was conducted with 26 men with the average age of 20, resulted higher plasma osmolality, degraded working memory and increased tension/anxiety and fatigue.

II. METHODS

A. Participants

Fully informed written consent was obtained from the subjects before the study. Sixty-two third year Medical student of Muhammadiyah Malang was sellected by questionnaires to determine their mental and physical health, age (20-15 yeard old) and body mass index (18,5-24,9). Student who has or ever had history of renal diseases, neurologic diseases, head trauma, physiological disturbance and malnutrition is excluded from participation. 62 subjects was divided in two groups, intervention group and control group.

B. Experimental Protocols

One day before intervention, subject was instructed to have enough night sleep (5-8 hours), not doing hard physical activity, not to consume alcohol, coffee, electrolyte drink since 12 hours before intervention. To disguise the experimental conditions, the researcher was helped my 5 volunteers as the examiners test the subjects (body weight and STM test), and subjects was blind to their body mass and STM test. For the intervention group, on the morning of each intervention, body weight of subject was measured by volunteer, and then subjects held the STM pretest. After pretest, subject performed treadmill walking exercise 5,6 km/h, grade 5%, room temperature (27,6 ± 0,8 ^{O}C) for 40 minutes non-stop. After exercise, subjects took 20 minutes to for rest, dry their skin and hair with paper towel, rested on a chair but didn't take water or food. After 20 minute rest, subject's weight was measured again. Subjects who lost ≥1% of body weight ongoing posttest with the same instruction. Subjects who finished the posttest was given food and drinks, as the end of the experimental procedure. For the control group, subjects performed pretest immediately with no intervention and weight measure, and did posttest an hour after the pretest with no fluid intake restriction. Control group subject got the same instructions 12 hours before the test as well as intervention group.

C. STM Function Assessment

Wechsler Adult Intelligence Scale (WAIS) was used as the instrument for this study, which was Digit span backward auditory recall to assessed STM function. It consist of several digit of numbers and subject was instructed to repeat the number backward after the examiner, with the same speed (one second for each space and digit). it started from 2 digit numbers until 7 digit numbers. Score was determined by the last number of digit that subject can repeat fluently.

D. Statistical Analysis

With IBM SPSS v20.0, Two groups of data (intervention and control) was analyzed using Chi-Square 2x2 table (dehydration-non dehydration and decreased score-non decreased score). Due to variability in rate and extent of dehydration over the course of the dehydration and non-dehydration experiments, statistical comparisons for all dependent variables were conducted only when a volunteer attained a level of dehydration ≥ 1% body mass loss. A criterion of ≥1% was established, because this is the lowest level of dehydration that has been suggested as capable of altering cognitive function. A P value of ≤0.05 (2-tailed) was the criterion for significance.

III. RESULTS

Experiment was conducted in Brawijaya Sport Center, Cikampek road No. 1, Malang in 2 months. 100% of 31 subjects in Intervention group loss ≥1% of weight, with mean body mass decreased was 1.733%, 1.02% minimum and 4.86% maximum (Table 1). 100% of intervention subjects fulfil the requirement of acute mild dehydration criteria which was expected. During intervention there was no unwanted symptom reported. Control group experienced no dehydration induction and no weight loss.

Table 1. Weight lost percentage based on age in intervention group

Age (Year)	% Weight loss				
	1-1,5%	*1,5-2%*	*2,5-3%*	*>3%*	*Total subject*
20	6	4	2	1	13
21	9	2	2	-	13
22	1	2	-	1	4
23	1	-	-	-	1
Total Subject	17	8	4	2	31

1% weight loss is equivalent with 1% body fluid loss in intervention subjects

STM function was tested to both groups. Normal score of WAIS Digit span Backward is ≥3. The table showed after intervention was conducted total dehydration subjects with normal score (≥3) decrease from 24 subjects (pretest) to 19 subjects (posttest). Total subjects with degraded score (< 3) increase from 7 subjects to 12 subjects. Mean score for Pretest to posttest in intervention group decreased from 3.55 to 3.06. Based on age, subjects who was 20 years old and 21 years old experienced degraded mean score, while subjects who were 22 and 23 years old has constant mean score (Table 2).

Table 2. Wais digitspan backward test score on intervention group (dehydration)

	Pre-test Score							Post-test Score						
Age (Year)	***2***	***3***	***4***	***5***	***6***	***7***	***Mean***	***2***	***3***	***4***	***5***	***6***	***7***	***Mean***
20	3	3	4	3	-	-	3,54	6	-	6	1	-	-	3,15*
21	2	2	8	-	1	-	3,69	3	6	3	1	-	-	3,15*
22	1	2	-	1	-	-	3,25	2	-	1	1	-	-	3,25
23	1	-	-	-	-	-	2	1	-	-	-	-	-	2
Total subject	7	7	12	4	1	0		12	6	10	3	0	0	

Symbol * on posttest refers to degraded score indicated STM function Impairment.

Table 3. Wais digitspan backward test score on control group (non-dehydration)

	Pre-test Score							Post-test Score						
Age (Year)	***2***	***3***	***4***	***5***	***6***	***7***	***Mean***	***2***	***3***	***4***	***5***	***6***	***7***	***Mean***
20	2	5	5	1	1	1	3,80	1	4	6	2	1	1	4,06**
21	-	5	4	-	1	-	3,70	-	4	3	2	1	-	4**
22	1	1	3	1	-	-	3,66	1	-	2	2	1	-	4,33**
23	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total subject	3	11	12	2	2	1		2	8	11	6	3	1	

Symbol ** on posttest refers to increased score indicated there was no indication of STM function Impairment.

Total of control subjects with normal score increase from 28 (pretest) to 29 subjects (posttest). While total of control subjects with degraded score decrease from 3 to 2 subjects. Mean score of pretest and posttest was increased in control group from 3.81 to 4.10. based on age, all age group (20, 21, 22 years old) showed increased mean score. (Table 3).

Quantitative description using Chi-Square, in intervention group, 16 subjects (51.61%) didn't show any degraded score and 15 subjects (48.39%) decreased in score. In control group, 28 subjects (90.32%) had not degraded score, and 3 subjects (9.68%) had degraded score. These showed that there are more dehydration subject experienced STM function impairment (48.39%) than non-dehydration subjects (9.68%). (Table 4) Chi-Square 2 tailed test showed significance of 0.001. (Table 5).

Table 4. Quantitative description of degraded and not degreaded score in intervention and control group

	Not degraded (%)	**degraded (%)**
Control Group/Non-dehydration	28 (90.32)	3 (9.68)
Intervention Group/Dehydration	16 (51.61)	15 (48.39)
Total	22 (71)	18 (29)

Table 5. statistical analysis with chi-square

	Asymp. Sig (2-sided)
Pearson Chi-Square	0,001

Significance value less than 0,05 showed significance rellation between variable.

IV. DISCUSSION

There are more subjects in intervention group had lower posttest score of WAIS digit span STM test than control group. WAIS digit span test score indicated acute-reversible
STM function impairment due to dehydration (≥1% loss of body fluid).

[1] During treadmill exercise, epinephrine and norepinephrine hormones are secreted by the adrenal medullae. Energy demand of muscle cells increase, followed by increasing of metabolism rate. This process causes higher body temperature. The body needs to lose excessive amounts of heat produced by the active muscles. These hormones stimulate sympathetic autonomic nervous system to activate apocrine gland that produce sweat. Apocrine glands secrete body fluid, NaCl and urea from blood capillary to form sweat and release it through the skin pores.

[15] The findings of previous study was conducted with 26 healthy male with the same procedure and cognitive test using computer based test, showed that dehydration affect cognitive, mood, anxiety and higher plasma osmolality value (examined by urine specific gravity). [14] In the next year, this experiment was continued to examine 25 healthy women with the same procedure. This study showed significant impairment in mood state and headache complain while cognitive function was not affected in woman. [11] Another study used 2 hours ergocycle for dehydration induction in 10 healthy endurance-trained male subjects, resulted 3% body mass reduction, cerebral blood flow was examined and resulted lower blood volume in the brain, lower blood flow velocity in internal, external and common carotid artery, also lower blood flow velocity in middle cerebral artery.

[10] 15 subjects experienced 12 hours fluid restriction method for inducing dehydration showed decrease of Na^+, K^+, H_2O and glucose level (8.7±6.8 mg/dl), higher plasma osmolality by 0,67% which caused cell shrinking and decreased brain volume (cerebral cortex, substantia alba and hypothalamus/thalamus). [12] 3 days dehydration diet method was conducted to induced dehydration on 6 subjects resulted 2.3% mean weight loss, decrease ventricle volume which leads to lower cerebrospinal fluid production by the fourth ventricle.

Despite the significance result in Chi-Square test, in this investigation, we see there are some subjects in control group that experienced STM function impairment as well as intervention group that did not experience STM function impairment. Some subjects showed adverse result from what was expected. These finding are caused by multiple confounding factors that beyond the control of researcher may affect the subject's STM function beside dehydration, which are [16] Neuromodulator level (higher dopamine level could increase AMPA and NMDA receptor activity, adrenalin involves emotional aspect and it increase the effectivity of limbic system, higher corticosteroid stress hormone makes the memory is easier to re-call while prolonged stress could impair this function), habit or memorizing practice will ease the process of consolidation, [17] light exposure activates PAK1 (p21-activating kinase 1) and this enzyme modulates hippocampus-dependent memory, [18] sleep quality (90 minutes of nap and longer REM state duration were proved to have better short term memory function because prefrontal cortex circulation is increased during REM state of sleep), [19] air pollution (NO_2 level more than 20 pbb is related to worse memory and logical function, O_3 level higher than 49pbb is related to worse executive function, thickening of internal carotid artery which decrease cerebral blood flow, free radical on contamination in blood impairs fat, nucleic acid and neuron protein which lead to neuro inflammatory response, neurodegenerative and blood brain barrier damage), [20] person who used to do music training since 8 years old was proven to have better concentration ability, [21] extensive cognitive learning (magic trick, reading, studying color, motoric activity, video game, mediation) for 14 weeks showed increase of grey matter, especially in fronto-parietal region.

In conclusion, this study demonstrates that, in third year male medical students, mild dehydration of ≥ 1% body mass loss induced result in adverse change in STM function assessed by WAIS backward digit span. Future studies should consider to control more confounding factors, determine the effect of chronic dehydration on cognitive function and to assess the effects of dehydration in cognitive function in at risk population such as elderly, diabetes patient, or stroke.

ACKNOWLEDGMENT

The Authors thank dr Irma Suswati, M. Kes as the Dean of medical faculty in the university of Muhammadiyah Malang for the support on this research, dr Mochamad Ma'roef, Sp.OG as Vice Dean 1, to examine this research with manuscript revision and submission, dr. Djaka Handaja, MPH as the chairman of the ethics commission, for ethical clearance approval. The authors wrote the manuscript and had primary responsibility for its final content. All authors read and approved the final manuscript.

REFERENCES

[1] Guyton, Arthur C. Textbook of Medical Physiology. Philadelphia: Elsevier Inc. Unit V. Chapter 26. Urine formation by the kidney dan Unit IX. Chapter 46. Sensory receptor, neural circuit for processing information. pp. 307-604. 2012. In press.

[2] Gustam. Risk Factor of Dehydration in Adolescent and Adult. Journal of Agricultural Institute Bogor. *Faktor*

Risiko Dehidrasi pada Remaja dan Dewasa. Jurnal institut Pertanian Bogor. pp. 27-66. 2012. In press.

[3]Pego, C. Ferreira, et al. Total Fluid Intake and Its Determinants: Cross-sectional Surveys Among Adult in 13 Countries Worldwide. Europe Journal of Nutrition 54. 2015. In press.

[4] Penggalih, Mirza Harapan Sakti titis, Zaenal Mutaqien Sofro, Eka Roshifita Rizqi, and Yuniko Fajri. Prevalence of Dehydration among Students in Gadjah Mada University. *Prevalensi Kasus Dehidrasi Pada Mahasiswa Universitas Gadjah Mada*. Pp. 3-10. 2013. Unpublished.

[5]Syaifuddin. Human Body Physiology, *Fisiologi Tubuh Manusia.* Jakarta: Salemba Medika Publisher. 2009. In press.

[6]Johnson, Michael D. Human Biology Concept and Current Issues. San Francisco:Pearson Education Inc. 2008. In press.

[7] Tantomi, Achmad Iwan, Abdurrachman Omar Baabdullah,and Andri Sagita. Trend of Early Senility Phenomenon as an Suspect of Demensia Symptom. *Tren Fenomena 'PisiDi' (Pikun Usia Dini) Sebagai Dugaan*
Awal Gejala Demensia. Journal of Islam Malang University. pp. 2-4. 2013. Unpublished.

[8] Sitohang, Nur Asnah, and Farida Linda Sari Siregar. Effect of Nutrition Therapy Dates for Short Term Memory of Students at Elementary School
60 886 and 060 889. Journal of Nursing and Health Care (JNHC) Vol.2 No.2. Pp:87-89. 2015. In press.

[9]Esmaeilpour, Khadijeh, Vahid Sheibani and Hakimeh Saadati. Caffeine Improved Spatial Learning and Memory Deficit in Sleep Deprived Female Rat. Journal of Iranian Society of Physiology and Pharmacology 121-129. Pp:123-127. 2015. In press.

[10] Biller, A, et al. Responses of the Human Brain to Mild Dehydration and Rehydration Explored In Vivo by H-MR Imaging and Pectroscopy. AJNR AM J Neuroradiol 36:2277-84. Pp: 2279-2283. 2015. In press.

[11] Trangmar, Steven J. et al. Dehydration Accelerates Reduction in Cerebral Blood Flow During Prolonged Exercise in the Heat Withpout Compromising Brain Metabolism.American Physiological Society. ISSN 0363-6135. Pp: H1600-H1603. 2015. In press.

[12] Streitburger, Daniel Paolo, et al. Investigating Structural Brain Changes of Dehydration Using Voxel-Bsed Morphometry. Volume 7, Issue 8. Pp. 7. 2012. In press.

[13] Lieberman, Harris R. Methods for Assesing the Effects of Dehydration on Cognitive Function. Suplement Article Nutrition Reviews. pp. 143-145. 2012. In press.

[14] Armstrong, Lawrence E,et al., 'Mild Dehydration Effects Mood in Healthy Young Women'. TheJournal of Nutrition Ingestive Behavior and Neurosciences. pp. 383-385. 2011. In press.

[15] Ganio, Matthew S,et al., 'Mild Dehidration Impairs Cognitive Performance and Mood of Men. British Journal of Nutrition. pp. 1536- 1541. 2011. In press.

[16] Stern, Sarah A, and Cristina M Alberini. Mechanisms of Memory Enhancement. National Institude of Health. 2014. In press.

[17] Shan Li-Li, et al, Light Exposure Before Learning Improves Memory Consolidation at Night. Scientific Report 5:15578. Pg. 3-8. 2015. In press.

[18] Lau, Esther Yuet Ying Lau, Mark Lawrence Wong, Kristy Nga Ting Lau, Florence Wai Ying Hui, Chia-Huei Tseng. Rapid-Eye-Movement- Sleep (REM) Associated Enhancement of Working Memory Performance after a Daytime Nap. Journal Pone 0125752 University of Hongkong. Pg.3-12. 2015. In press.

[19] Gatto, Nicole M, et all. 2015. Components of Air Pollution and Cognitive Function in Middle Aged and Older Adults in Los Angeles. Neurotoxicology National Institude of Health 40: 1-7/ doi:10.1016 pg. 5-
8.In press.

[20] Suarez, Lidia. Shalini Elangovan, and Agnes Au. 2016. Cross-sectional Study on the Relationship Between Music Training and Working Memory in Adult. Australian Journal of Psychology. DOI: 10.111/ajpy.12087. pp. 40-42. In press.

[21] Koch, Kathrin, Tim Jonas Rees, Oana Georgina Rus and Claus Zimmer. 2015. Extensive Learning is Associated with Gray Matter Changes in the Right Hippocampus. NeuroImage Journal, Elsevier Inc. DOI:10.1016. Pp. 2-5.Inpress.